21SEP23

Thursday, September 21, 2023 5:58 PM

Today's class.

① At the end we want to get dynamic Model of AC machine in form.

Rotating Field machines

$$[\dot{x}] = [F(x)][u]$$

② The model will be based on Space vectors

Must know

- Principle behind Space vectors
- Definition
- Conversion.

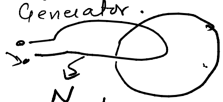
① What do we mean by Rotating Field machines?

– Rotating magnetic field

Faradays law

$$v_i = \frac{d\psi}{dt} = N\frac{d\phi}{dt}$$

Generator



N

Flux linkage $\psi = N\phi(t)$

magnetic Flux physics

$\phi(t)$

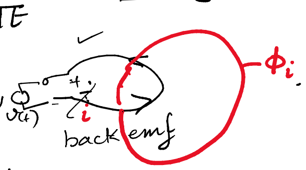
$$\boxed{\psi = N\phi = \boxed{L} I}$$

turns, coil, electrical circuit

Lenz' law

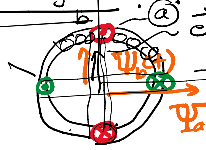
Biot Savart law

Q2 How can you produce rotating magnet?



$v(t)$, i, back emf, ϕ_i

Stator



$\vec{e}_b = 1e^{j\frac{\pi}{2}}$

$\vec{e}_a = 1e^{j0}$

$\Psi_a(t)$, $\Psi_b(t)$

① 2 windings minimum required. why?

and

② $I_a = I_m \cdot \cos(\omega t)$

$I_b = I_m \cdot \sin(\omega t)$

① Rotating magnetic field means = Flux linkage.

$$\Psi_a(t) = L_a \cdot I_m \cdot \cos(\omega t)$$

$$\Psi_b(t) = L_b I_m \cos(\omega t)$$

Resultant Flux linkage is a vector

not yet complete

$$\vec{\Psi}_s(t) = \Psi_a(t) 1e^{j0} + \Psi_b(t) \cdot 1e^{j\frac{\pi}{2}}$$

$$= \Psi_a(t) + j\,\Psi_b(t)$$

Space vector

Spatial orientation of resultant flux linkage at any given time.

$L_a = L_b = L_m$

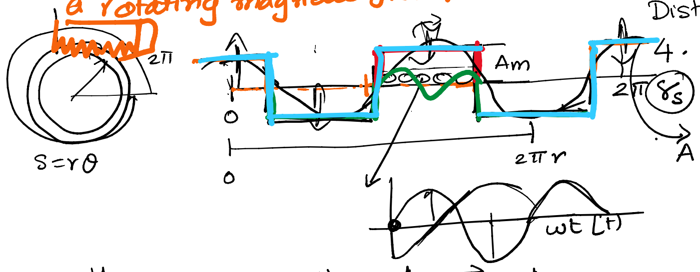
$$\therefore \vec{\Psi}_s(t) = L_m I_m \cdot \cos(\omega t) + j L_m I_m \cdot \sin(\omega t)$$

IMP

$$\boxed{\vec{\Psi}_s(t) = L_m \cdot I_m \cdot e^{j(\omega t)} = \Psi_m \cdot e^{j(\omega t)}}$$

magnitude

We need 2 quadrature winding fed with 2 phase currents (90° phase shifted to produce a resultant flux linkage vector whose tip .. follows a circular ~~tag~~ trajectory to signify a rotating magnetic field.



2π, $s = r\theta$, 0, $2\pi r$, Am, 2π, θ_s, ωt (t)

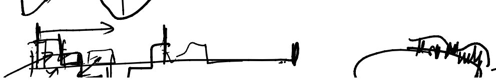
Distributed windings

$\ominus$ = MMF = N.I

Space harmonics

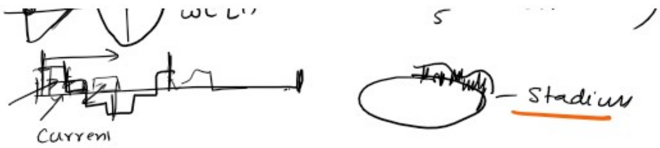
$$A = \frac{4A_m}{\pi}\left(\cos(\theta) - \frac{1}{3}\cos(3\theta) + \frac{1}{5}\cos(5\theta)) - - - \right)$$

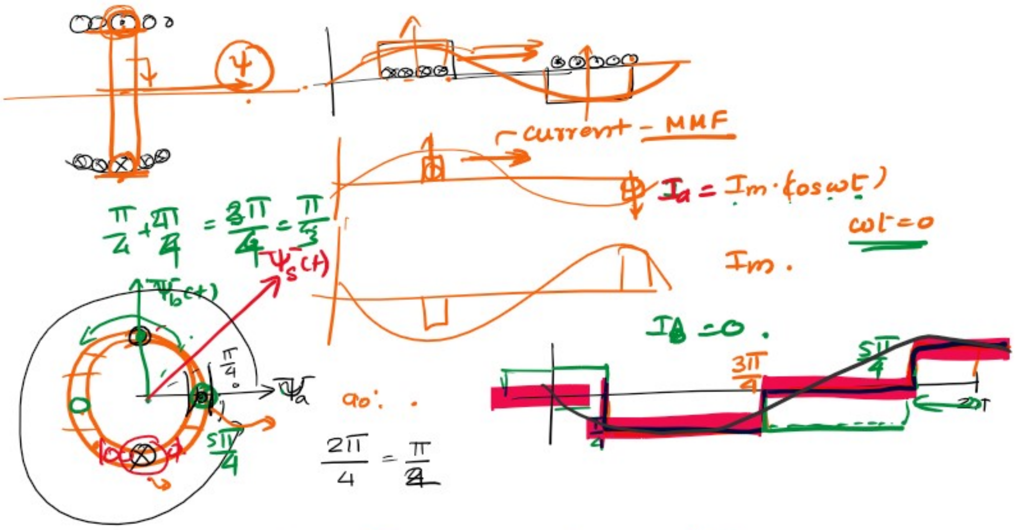
Imp ① "Mexican wave"



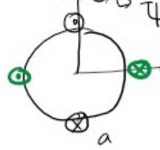
Stadium

Imp ① "Mexican wave"





$\frac{3\pi}{4} + \frac{\pi}{2} = \frac{3\pi + 2\pi}{4} = \frac{5\pi}{4}$ $\qquad$ $\frac{5\pi}{4} + \frac{\pi}{4} = \frac{6\pi}{4} = \frac{3\pi}{2}$.



$\Psi_b(t) = L_m I_m \cdot \sin(\omega t)$

$\Psi_a(t) = L_m \cdot I_m \cdot \cos(\omega t)$

$I_m = 1$

$\cos(\omega t)$

$\sin(\omega t)$

$\vec{\Psi}_s(t) = \Psi_a(t) + j\,\Psi_b(t)$

$\boxed{\vec{\Psi}_s(t) = L_m \cdot I_m \cdot e^{j\omega t}}$ ← I can define this in a complex plane.

Q3 But we have 3 phase windings. 3 phase currents.

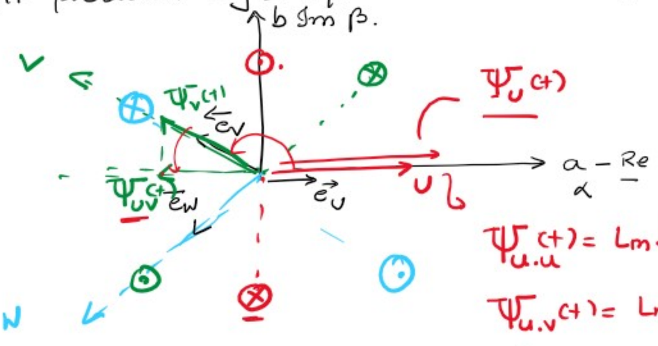
$I_U(t) = I_m \cdot \cos(\omega t)$

$I_V(t) = I_m \cdot \cos(\omega t - 2\pi/3)$

$I_W(t) = I_m \cdot \cos(\omega t - 4\pi/3)$

How do we produce a rotating magnetic field... Same as ~~similar~~

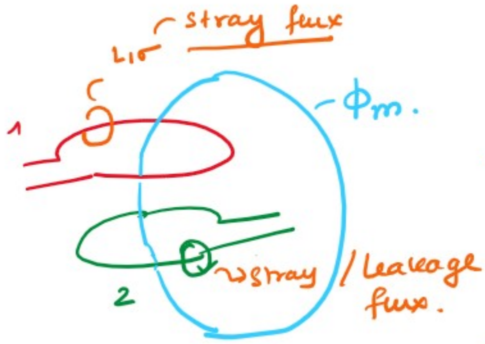
3 RMF produced by 2 quadrature winding system.



$\Psi_{U.U}(t) = L_m \cdot I_U(t)$

$\Psi_{U.V}(t) = L_m \cdot I_V(t)$

$\Psi_{U.W}(t) = L_m \cdot I_W(t)$



$L_m = \Psi_m = \frac{\Phi}{I}$

mutual

Φ_m - mutual flux is flux linking Any 2 coils mutual.

$\Phi_T = \Phi_m + \Phi_{1\sigma}$

2 ... flux.

$$\Phi_T = \Phi_m + \Phi_{1\sigma}$$

$$L_{selfinductance} = L_m + L_\sigma$$

Space vectors for 3phase Machines:

The resultant flux linkage vector produced by 3phase Windings (with 3phase currents) ... which would be Same as that produced by 2 phase Quadrature axis winding.

1. Thought experiment

$L_m = 1.0$, $I_u = 1\cdot\cos(\omega t)$ $I_V = 1\cdot\cos(\omega t - 2\pi/3)$, $I_W = 1\cdot\cos(\omega t - 4\pi/3)$.

$\omega t = 0$

$$\vec{\Psi}_s = \Psi_U(t) + \Psi_V(t)\cdot\vec{e}_V + \Psi_W(t)\cdot\vec{e}_W$$

$$\vec{e}_V = e^{j2\pi/3} = -\frac{1}{2} + j\frac{\sqrt{3}}{2} \quad \vec{e}_W = e^{j4\pi/3} = -\frac{1}{2} - j\frac{\sqrt{3}}{2}.$$

$$\boxed{\vec{\Psi}_s = \frac{3}{2}}$$

∴ Definition of Space vector is

$$\vec{\Psi}_s(t) = \frac{2}{3}\left(\Psi_U(t)\cdot\vec{e}_U + \Psi_V(t)\,\vec{e}_V + \Psi_W(t)\cdot\vec{e}_W\right)$$

$$\vec{a} = \vec{e}_V = e^{j2\pi/3} \quad \therefore \vec{e}_W = \vec{a}^2$$

$$\boxed{\therefore \vec{\Psi}_s(t) = \frac{2}{3}\left(\Psi_U(t) + \Psi_V(t)\cdot\vec{a} + \Psi_W(t)\,\vec{a}^2\right)}$$

Complex phasor

$$r = A\cdot\cos(\omega t) \qquad r_2 = A\cdot\cos(\omega t - \phi)$$

$$= \frac{|A|e^{j0}}{\sqrt{2}}_{RMS} \qquad = \frac{|A|\cdot e^{-j\phi}}{\sqrt{2}}.$$

What the hell is Parks Transform?

$$\frac{2}{3}\left(\Psi_U(t) + \vec{a}\,\Psi_V(t) + \vec{a}^2\Psi_W(t)\right)$$

$$\underbrace{\begin{bmatrix} \Psi_{s\alpha} \\ \Psi_{s\beta} \end{bmatrix}}_{2\times1} = \frac{2}{3}\,\vec{C}_{sv}\underbrace{\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}}_{2\times3}\underbrace{\begin{bmatrix} \Psi_U \\ \Psi_V \\ \Psi_W \end{bmatrix}}_{3\times1}$$

$$\begin{bmatrix} \Psi_U \\ \Psi_V \\ \cdots \end{bmatrix} = \frac{2}{\cdots}\begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{\cdots} \\ \cdots & \cdots \end{bmatrix}\begin{bmatrix} \Psi_{s\alpha} \\ \Psi_{s\beta} \end{bmatrix} \qquad \vec{C}_{sp} = \vec{C}_{sv}^T$$

$$\begin{bmatrix}\psi_U\\ \psi_V\\ \psi_W\end{bmatrix} = \frac{2}{3}\begin{bmatrix} & \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2}\end{bmatrix}\begin{bmatrix}\psi_{s\alpha}\\ \psi_{s\beta}\end{bmatrix}$$

Home work → Solve how to convert Space vectors → 3phas

⊕ use $x_U + x_V + x_W = 0$. → $\psi_{s\alpha} = \psi_U$.

ψ_V, ψ_W

ψ → Faradays $v = \frac{d\psi}{dt}$.

mathematical models.

$\vec{V_s} = \frac{2}{3}\left(V_U(t) + \vec{a}\, V_V(t) + \vec{a}^2 \cdot V_W(t)\right)$.

$\psi = Li$.

$\vec{I_s} = \frac{2}{3}\left(I_U(t) + \vec{a}\, I_V(t) + \vec{a}^2 I_W(t)\right)$

$v = \frac{d\psi}{dt}$, ohm – $v = Ri$

$V_U = R_U \cdot I_U + \frac{d\psi_U}{dt}$.

$$\boxed{\vec{V_s} = R_s \cdot \vec{I_s} + \frac{d\vec{\psi_s}}{dt}}$$ whole stator winding 3p.

Rotor

$$\boxed{\vec{V_R} = R_r \cdot \vec{I_r} + \frac{d\vec{\psi_r}}{dt}}.$$